Environmental Impact Assessment Report

Chapter 4 The Scheme

Grangemouth Flood Protection Scheme 2024
Falkirk Council

GRANGEMOUTH
Flood Protection Scheme
Protecting the heart of our communities

Grangemouth Flood Protection Scheme

Environmental Impact Assessment Report

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Acronyms

CEMP	Construction Environment Methodology Report
EIA	Environmental Impact Assessment
FRMS	Flood Risk Management Strategy
HRA	Habitats Regulations Appraisal
HES	Historic Environment Scotland
LFRMP	Local Flood Risk Management Plan
NMU	Non-Motorised Users
PLP	Property Level of Protection
PVA	Potentially Vulnerable Area
SEPA	Special Protection Area
SuDS	Sustainable Urban Drainage System

4. The Scheme

4.1 Introduction

This chapter provides a description of the proposed Grangemouth Flood Protection Scheme ('the Scheme') design at the outline design stage, as promoted by Falkirk Council under Part 4 of the Flood Risk Management (Scotland) Act 2009 (the FRM Act), and The Flood Risk Management (Flood Protection Schemes, Potentially Vulnerable Areas and Local Plan Districts) (Scotland) Regulations 2010 as amended by The Flood Risk Management (Flood Protection Schemes, Potentially Vulnerable Areas and Local Plan Districts) (Scotland) Amendment Regulations 2017 (the FRM Regulations) (refer to Chapter 1: Introduction).

The evolution of the alternative Scheme options, the evolution of the preferred design and the likely construction methods for the Scheme are also provided.

The assessment of impacts and effects and the mitigation measures identified in this EIA Report (Chapters 6-14) are based on the outline Scheme design as described in this chapter.

4.2 Scheme evolution and alternatives appraisal process

4.2.1 Introduction

This section describes the evolution of the Scheme from its requisite identification in the Forth Estuary Local Plan District Flood Risk Management Strategy (FRMS) (SEPA, 2015) (as discussed in Chapter 1, Section 1.3) to the detailed options appraisal process undertaken by Jacobs, Falkirk Council and a number of stakeholders between 2011 and 2019 (refer to Appendix C4.1: Option Appraisal Summary Report).

4.2.2 Long list of options

An initial high-level appraisal of flood risk management options for the Grangemouth area (Potentially Vulnerable Area (PVA) 10 / 11) was undertaken by the Scottish Environment Protection Agency (SEPA) through the FRMS (SEPA, 2015) process, which was refined by local authorities in the development of the respective Local Flood Risk Management Plans (LFRMPs) (refer to Chapter 1: Introduction, for further information on the FRMSs and LFRMPs). Diagram 4-1 shows the flood risk management options that were considered for PVA 10 / 11 that encompasses the Grangemouth area, with options shaded green indicating those to be taken forward by either SEPA or Falkirk Council for further investigation.

Flood protection scheme/works	*Natural flood management works*	New flood warning	Community flood action groups	*Property level protection scheme*	*Site protection plans*
Flood protection study	*Natural flood management study*	Maintain flood warning	Awareness raising	Surface water plan/study	Emergency plans/response
Maintain flood protection scheme	Strategic mapping and modelling	Flood forecasting	Self help	Maintenance	Planning policies

Diagram 4-1: Summary of SEPA's actions to manage flooding in PVA 10 / 11 (SEPA, 2015)

While the Forth Estuary Local Plan District FRMS ruled out the potential for natural flood management measures and property level protection to provide sufficient flood protection as stand-alone measures, both were considered further as complimentary measures to what could, mainly, be delivered by a flood protection scheme.

Jacobs (formerly Halcrow and CH2M) was subsequently appointed by Falkirk Council to conduct a flood protection study for the PVA, which started with the development and review of a long list of potentially feasible flood protection measures (options), as shown in Table 4-1. This long list was reviewed to establish which options could be taken forward to the detailed appraisal stage which is also indicated in Table 4-4-1.

The options were compared in terms of their anticipated outcomes and any major constraints, with the two following 'control' options being discounted:

- Do Nothing: considers the future baseline situation with no intervention. Given the predicted damage, cost and health risk associated with future flood events, this option was discounted.
- Do Minimum: assumes Falkirk Council's existing flood risk management assets are maintained over time. This includes removing debris and sediment at structures and ensuring existing embankments and walls are maintained. However, it does not involve raising the heights of flood defences to account for increased flood risk associated with the effects of climate change. It also does not include for any regular inspection and maintenance of the extensive embankments and walls located within privately owned land (Forth Ports and operators within the petrochemical plant), as Falkirk Council is not responsible for these structures. This option was therefore also discounted due to the uncertainty of the robustness of existing defences and the increasing health risks and cost associated with increasing flood risk over time.

Table 4-4-1 shows the long list of design options, summarises their appraisal and identifies which were taken forward for more detailed consideration.

Table 4-4-1: Summary of long list design options

Option Description	Options Appraisal Conclusion	Taken Forward for More detailed Appraisal
Direct Defences e.g. flood walls and embankments	Flood walls and embankments will provide improved protection from fluvial and tidal flood risk throughout the study area.	Yes

Option Description	Options Appraisal Conclusion	Taken Forward for More detailed Appraisal
Runoff Control natural flood management measures e.g. woodland planting, land management, wetland creation, upland drain blocking	The Forth Estuary Local District FRMS identifies runoff control as not practical for the size of watercourses in the scope of the works. Creation / restoration of wetlands / ponds were considered further as additive options along with flood storage and channel realignment options.	Only as an additive option (i.e to support other design options)
River / Floodplain Restoration e.g. floodplain reconnection, stream blocking, floodplain / riparian woodland, reach restoration	Some potential for floodplain reconnection through small scale channel realignment of a section of the Rivers Carron and Avon were considered further, while large scale river and floodplain restoration measures were not deemed suitable principally due to land use pressure.	Yes (but not as standalone measure as limited capacity to develop such at a larger scale)
Sediment Management e.g. dredging, sediment traps, bank restoration	No evidence of excessive sediment deposition was found in the channels; requires ongoing management and is not cost effective; tidal influence on lower reaches of water courses makes sediment removal unsustainable. All the existing banks are vegetated and, due to high land use pressure (urban environment), there is limited available space for bank restoration other than at the flood relief channel.	Yes – potential bank/ channel restoration at the Flood Relief Channel/Grange Burn.
Wave Attenuation e.g. beach recharge, shingle re-profiling, sand dune restoration	These measures were deemed impractical due to the potential adverse impact on Grangemouth port operations.	No
Surge Attenuation e.g. removing embankments round fields adjacent to the coast	Surge attenuation measures would not reduce flood levels due to the large land take required and the fluvial influence of watercourses.	No

Option Description	Options Appraisal Conclusion	Taken Forward for More detailed Appraisal
Online and Offline Storage e.g. Developing upstream reservoirs or large areas that can be safely flooded during high rainfall events, thereby limiting downstream flows for limited periods	Online and offline storage was largely discounted due to insufficient space available to create storage areas capable of storing the volume of flood water required. The capacity for flood storage at the Carron Valley Reservoir was considered and rejected as it would be unlikely to substantially reduce flood peaks at Carronshore, and it would not reduce peak flows in the other watercourses. Two potential flood storage areas were then identified directly upstream from the Carron Dams site and upstream from Stirling Road. Approximately 3 km of structures would have been required to impound water and not increase flood risk elsewhere. Several constraining factors resulted in their rejection including the presence of existing infrastructure (electricity pylons, gas mains, roads, properties) a landfill-site and cemetery. Two discreet potential flood storage areas were considered further: new online storage dam on the Westquarter Burn (tributary of the Grange Burn) near Grandstable Cemetery; and set-back embankment flood storage within Zetland Park.	Yes – floodplain areas identified at the Westquarter Burn and Zetland Park
Modification of Conveyance e.g. channel modifications, diversion channel, channel realignment, culvert modifications, removal of hydraulic constrictions (bridges and pipe bridges), bridge modifications	Due to the urban environment, measures to modify conveyance in town were limited, while small realignments on the Rivers Carron and Avon were considered further. A flood relief channel already exists on the Grange Burn and its modification forms part of proposed options. New flood relief channels were discounted as they would not address tidal flood risk, there would be significant consenting constraints and they have a relatively high capital cost when considered against the limited benefit they might provide. Bridge conveyance (and modification) was investigated and discounted.	Yes - small realignments on the Rivers Carron and Avon and modifications to the flood relief channel. [Note that the Scheme design now includes culvert and bridge modifications (refer to Section 4.3)].
Fluvial Control Structures e.g. sluice gates / penstocks / flap valves, weirs, trash screens, pumping stations	Due to the size and predicted flows on the watercourses in the scope of works, it is not practical or feasible to install fluvial control measures. Some of the fluvial control measures will be re-assessed as secondary drainage measures.	Only as secondary drainage measures

Option Description	Options Appraisal Conclusion	Taken Forward for More detailed Appraisal
Coastal Control Structures e.g. revetments, groynes, breakwaters, artificial reefs, gates and tidal barriers	Due to the land take required and sensitive environmental classification of the Forth Estuary, coastal control measures, such as the construction of a tidal barrier across the Forth Estuary, were not considered to be practical or technically viable as a standalone measure. However, revetments and a (local) tidal barrier at the mouth of the Grange Burn were considered further.	Yes - revetments and a tidal barrier on the Grange Burn
Sustainable Urban Drainage Systems (SuDS)	Deemed to offer no benefit in reducing flooding from fluvial and tidal sources due to the large, predicted flows. SuDS were considered for the secondary drainage aspect of the Scheme.	Only as secondary drainage measures
Watercourse Maintenance	Falkirk Council already undertakes regular watercourse inspections and maintenance activity to ensure compliance with the FRMA.	No
Property Level of Protection (PLP)	Not considered feasible as a standalone measure but considered further for specific locations.	Only as an additive option
Flood Forecasting / Warning	SEPA has implemented a flood forecasting and warning system on the Rivers Carron, Avon and Grange Burn, and the Forth Estuary.	No
Self Help	Includes raising awareness, development of Flood Action Group and Business continuity plans. These measures were not standalone items but addressed through the Scheme and promoted by Falkirk Council.	No
Emergency Plan	Falkirk Council already has an emergency flood plan; however, this will need to be updated to account for the Scheme defences.	No

Examples of reasons for discounting options from the long list included:

- lack of hydraulic benefit;
- very high capital costs, such as to make the option unviable (i.e. >£100M, per option);
- significant likely adverse environmental or social impacts (such as significant damage to the Frontiers of the Roman Empire (Antonine Wall) World Heritage Site or creating physical obstructions that would reduce access to community facilities or create barriers within communities);
- physical limitations such as lack of space to place the measure; and
- significant difficulties in constructing new assets.

Although some of the long list options were discounted as stand-alone options for technical reasons, some were taken forward as potential measures to add to other options where they helped deliver scheme objectives. For example, the primary reasons for not taking catchment-wide natural flood management as a stand-alone option forward related to:

- the difficulties in quantifying the reduction in flood risk from natural flood management;
- it would not improve coastal flooding in lower reaches of all three catchments;
- the large scale of change in land management practices required would not be practical; and

- it would only have limited impact on reducing peak flows in the Rivers Carron, Avon and Grange Burn due to size of catchment and magnitude of flows.

Natural flood management measures do however offer multiple benefits through the potential creation of new habitats and amenity benefits, so they were considered as potential environmental mitigation or offset measures that can also provide some flood risk management benefit.

4.2.3 Options appraisal

A range of potentially feasible options was explored to identify flood risk management interventions for discreet areas exposed to flood risk, which were then assessed and ranked according to how well they performed against pre-defined criteria linked to the Scheme Objectives. The criteria were derived from the following themes:

- **Economic**: the benefit / cost ratio of the option based on an estimate of the damages avoided (i.e. the cost of estimated flood damages avoided over the expected 100 year lifespan of the Scheme) versus the construction and maintenance cost of the option for the period[1].
- **Environmental**: a high-level appraisal of the potential environmental impacts (e.g. damage to designated sites), opportunities (e.g. improvements to channel morphology and biodiversity) and risks (e.g. where it may be difficult to achieve environmental consent where potentially feasible options exist). A high-level carbon footprint appraisal for each option was also undertaken to inform the environmental score[2].
- **Social**: a high-level appraisal of the likely benefits (e.g. flood risk alleviation), opportunities and constraints (e.g. impact on views, access, open spaces etc).
- **Technical**: any particular technical risks associated with construction or operation of a particular option (e.g. difficulties from high-pressure pipelines, cabling and other utilities across the site).

The iterative process of assessing and discounting or refining options to identify the preferred option at each location was regularly informed by the review of more detailed flood modelling and other information, such as site inspections, detailed topographical surveys, landowner and site operator consultation. In addition, feedback was received on options from stakeholders, such as environmental consultees at workshops, Historic Environment Scotland (HES) on the potential effects on the Frontiers of the Roman Empire (Antonine Wall) World Heritage Site, and the public exhibition (Public Exhibition #1), where proposed options for Grangemouth town centre were presented on display boards in April 2018 (refer to Chapter 5: Stakeholder Engagement).

The main options that were considered in various combinations at the detailed option appraisal stage included:

- Direct flood defences (embankments or flood walls along the four main watercourses (River Carron, River Avon, Grange Burn and the Flood Relief Channel) at various positions (at bank-side or set-back) and lengths);
- Flow control structure on the Grange Burn (controlling flows into the burn and the flood relief channel from the Westquarter and Polmont Burn tributaries);
- Flood storage area on the Westquarter Burn requiring +4m high dam;

[1] Calculated using the Environment Agency 'Economic Appraisal Supporting Spreadsheets'. Online. Available at: https://www.gov.uk/government/publications/fcrm-economic-appraisal-supporting-spreadsheet (Accessed August 2019)

[2] Environment Agency carbon footprint tool is based on a length of flood defence, there is no accounting for height of flood defences or number of bespoke structures. Online. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/571707/LIT_7067.pdf (Accessed August 2019).

- Flood storage area within Zetland Park; and
- Tidal barrier at the mouth of the Grange Burn.

The main constraints associated with each of these options were identified as follows:

- Direct defences: concerns from residents about impacts on views, particularly at Grange Burn.
- Flow control structure: technical uncertainties regarding its efficacy, operation and maintenance.
- Flood storage at Westquarter Burn: consultation with HES indicated significant concerns due to the potential impact on the Frontiers of the Roman Empire (Antonine Wall) World Heritage Site.
- Flood storage in Zetland Park: public consultation indicated significant concerns regarding potential impacts on the park as a key open space in the town and the emerging Zetland Park Regeneration Project.
- Tidal barrier: Discounted due to very high cost and likely very significant environmental impacts. A tidal barrier in conjunction with flow control on the Grange Burn was discounted due to concerns surrounding the technical viability of this option and the significant risks associated with operating the structures. Option would only address tidal flood risk and could increase river flooding as rivers would not be able to discharge into the sea.

Given these constraints and stakeholder feedback, alternative options were developed, and the detailed hydraulic model was extended upstream to model flows from the M9 culvert along the Polmont and Westquarter Burns. An alternative solution was then developed which precluded the requirement for the flood storage areas on the Westquarter Burn and at Zetland Park as well as the tidal barrier option, but without raising the required height of direct flood defences at sensitive locations (i.e. in Zetland Park).

The options were refined further and appraised in more detail to identify the most appropriate measures at each location, which together form the preferred scheme option. With regard to designing the position and type of direct defences, a general preference was given for embankments where possible, as they:

- have a lower carbon footprint (as use less concrete than flood walls);
- allow mammals to pass between the aquatic and terrestrial habitats;
- can have relatively lower impact on visual amenity and landscape; and
- can be crossed by pedestrians, or even used as raised footpaths to improve access.

Where it was not possible to prioritise the selection of embankments over flood defence walls, the reasons generally included:

- space constraints (particularly within the vicinity of pipelines);
- challenging maintenance requirements (the Council would have a long-term vegetation control duty and needs to ensure options consider operation and maintenance); or
- economically favourable, i.e. cheaper to construct flood defence walls based on direct costs and / or time saved by using the same construction method.

With regard to establishing the standard of protection that would be provided by the Scheme, the Council aspired to a 1 in 200-year standard of protection[3].

[3] The 1 in 200-year standard of protection is a measure of the annual probability of flooding in any year (also referred to as 0.5% annual exceedance probability).

An appraisal of what additional defences would be required to deliver a scheme that protects against the effects of climate change over the design life (i.e. 100 years) revealed that the total required flood defence lengths would likely increase by 5-10 km while flood defence heights would increase further by an average of 1 m but potentially more than 2 m in a few locations along the required scheme alignment. Given the lower probability of an event occurring that exceeds the 1 in 200-year standard of protection (i.e. <0.5% probability in any year), it was concluded that the additional likely significant impact on the community associated with impacts on views, townscape and severance issues would be unacceptable, particularly considered against the probability and frequency of such extreme events occurring over the design life of the scheme. However, it was decided that some provision be made to allow the defences to be raised in future to account for the effects of climate change by over-engineering foundations and constructing heavily constrained sections (i.e. at the estuary frontage) to an increased height where required (refer to Section 4.3.2).

It was also noted that the Local District FRMSs are reviewed every six years, so the future risks and potential impacts, particularly associated with climate change, for the Grangemouth and surrounding areas will be re-assessed as deemed necessary, with the need for further interventions being identified in the future.

The Habitats Regulations Appraisal (HRA) process required a detailed review of options to investigate how to minimise the potential effects on the Firth of Forth Special Protection Area (SPA) (such as due to loss of designated habitat or disturbance to birds) and discussions on this have been held with NatureScot (refer to Chapter 7: Biodiversity for further details). The design also evolved through further consultation with the port and petrochemical plant operators to establish the absolute safe limit to which the proposed flood defence walls or embankments could be set back from the coast, such that they could be constructed without compromising safe operations and allow space for access and maintenance.

Once the distance that the flood defences could be set back from the Firth of Forth SPA perimeter was established, further study was required at certain locations to determine the minimum width (and therefore maximum steepness) of the rock armour revetment proposed on the wet-side that would be required to attenuate wave action. The rock armour extent was effectively reduced by increasing the gradient.

Other examples of how the design has been refined for environmental reasons are given in the description of mitigation embedded within the design in Table 4-2.

4.2.4 Design evolution for the Scheme and primary / embedded mitigation

Once the preferred scheme design had been identified, more detailed flood risk mapping was carried out, which assessed a combination of flood events from fluvial sources and coastal sources and included wave overtopping. The flood modelling estimated the likelihood and extent of flooding to inform the required height and extent of flood defences that would be required to provide the desired standard of protection during a combination of fluvial and coastal flood risk. The 1 in 200-year flood event is illustrated in Figure A1.2 in Appendix A.

Early iterations of the outline scheme design assumed embankments should be incorporated where feasible over walls due to their lower relative carbon footprint, their general offer of improved access and because they were considered to be less imposing on views and landscape than concrete walls. However, later design reviews noted that in areas less accessible or visible to the general public, sheet piling could feasibly be employed alone without the need to encase them in embankments or concrete walls, which would potentially reduce costs, construction time and embodied carbon. Consideration was also given to the potential to use spoil from construction to form landscaped embankments, which would potentially improve views, reduce waste, provide positive effects for biodiversity and contribute

to reducing overall embodied carbon. However, any such recycling of spoil cannot be confirmed until a contractor is appointed and an analysis of local available spoil characteristics is undertaken for its suitability to be used elsewhere.

In addition, a review of the need for sheet piling to provide seepage control under the flood defences and to confirm their structural requirements was undertaken and will be further refined during the detailed design phase, with an aim to reducing the overall requirement for steel and scheme embodied carbon.

The proposed area of development for the scheme which evolved (the Scheme) was divided into six discrete Flood Cell areas (Flood Cells 1-6) and these are shown in Figure A4.1a.

In order to avoid or reduce the environmental impacts of the Scheme, several primary mitigation measures were integrated into the Scheme design (primary or embedded mitigation). These measures were considered in the initial significance assessment before consideration of any additional secondary or tertiary mitigation and the assessment of residual significance of effects. These measures are outlined in Table 4-2.

Table 4-2: Mitigation measures integrated into the Scheme design (primary / embedded mitigation)

Flood Cell	Embedded Mitigation Measure	Justification / Value
1	Setting walls and embankments back from the River Carron, where feasible.	To maintain footpath access along the river, avoid impacting upon watercourses and riverbanks and to limit reductions of the floodplain.
	Varying the design characteristics of the Scheme (e.g. aligning footpaths on top of embankments, limiting the number of flood gates by using ground modelling to raise adjacent ground to meet paths at the top of embankments).	To integrate the Scheme more fully into the landscape. Incorporation of flood gates have been used where the raising of ground levels is not deemed practical.
	Ground raising to reduce the relative wall height adjacent to the Core Path between the river and the Dawson Mission.	To mitigate landscape and visual impacts at this location.
	Maintaining the level of the wall to the existing height and / or provide fencing adjacent to it, where the flood height level is lower.	To maintain privacy / screening.
3	The incorporation of toe protection at the seaward side of the proposed flood defences, where deemed necessary.	Potential effects due to wave scour will be reduced.
4	Removal of a proposed flood basin from the Scheme design.	To reduce the impact of the Scheme on the Frontiers of the Roman Empire (Antonine Wall) World Heritage Site (WHS) and avoid any Scheduled sections of the WHS.
	Alignment of the flood defences in Zetland Park.	Relocating a section of the proposed flood wall further from the watercourse will allow high value trees to be preserved.

Flood Cell	Embedded Mitigation Measure	Justification / Value
	Walkways north of Zetland Park raised to elevate the footpath slightly in various locations.	Reduces the height of the walls, allowing views over the top and potential access to the riverbank in places.
	Repositioning of the flood wall at Rannoch Park.	To enable retention of a long row of roadside mature trees. Due to the trees being infected with the Chalara Ash Dieback disease, as noted in the tree survey, these trees are now likely to be removed at some point in the future, however, the location of the trees are a key visual green element in the landscape, so would be replaced in the same location.
	Wall positioned at the edge of the carriageway along the length of the northern bank of the Grange Burn opposite Grange Road.	To enable the retention of riverbank planting which will maintain the existing screening of industrial units.
	Modifications to the design of the embankment in Zetland Park to make it look more natural.	The embankment will have a more natural appearance in the park.
	Repositioning of the wall along the Grange Burn in Zetland Park.	To enable the retention of mature trees.
	Removal of flood protection measures (direct defences) at / near the Frontiers of the Roman Empire (Antonine Wall) World Heritage Site.	To avoid encroachment into Scheduled section of the World Heritage Site.
6	Realignment of flood defences along part of the estuary frontage.	Realigning the flood defences at this location will reduce encroachment into the Firth of Forth SPA boundary.
	Soft engineered reinforced slope along the existing woodland next to the road at the far east of the flood cell (west of the water treatment plant). The previous proposal was to have rock armour as a coastal revetment.	To visually fit and match the adjacent landscape character.
	The incorporation of toe protection at the seaward side of the proposed defences, where deemed necessary.	Potential effects due to wave scour will be reduced.
General	Flood defences repositioned and realigned at various locations and / or set back to avoid severance impacts on watercourses.	To retain as many trees as possible to reduce potential impacts on landscape, visual and biodiversity receptors and the water environment; and to contribute to positive impacts on human health.
	Flood defence heights reduced where acceptable.	To avoid substantial effects on landscape and visual receptors in sensitive areas.
	Provision of flood gates and ramps along active travel routes to maintain access through and over the flood protection measures.	To reduce potential delays and optimise safety for users of active travel routes.
	Use of lower carbon construction materials to construct the Scheme.	To reduce potential greenhouse gas emissions associated with the Scheme.

4.3 Scheme description

4.3.1 Overview of the Scheme

The Scheme comprises a series of flood protection measures along the River Carron, River Avon, Grange Burn and Firth of Forth estuary. The outline design includes a series of new flood walls and embankments which, when combined, have an approximate total length of 28 km. Other measures comprise relining the flood relief channel, coastal revetment, a new flow control structure and modifications / replacements to bridges.

The Scheme will provide flood risk protection up to the 1 in 200-year level. In addition to protecting against coastal flood risk from the Firth of Forth, the Scheme will address fluvial flood risk, primarily from the Rivers Carron and Avon, the Grange Burn and associated flood relief channel, as well as short sections of their tributaries (the Westquarter, Polmont, Chapel and Millhall Burns). Overall, the Scheme is anticipated to protect 2,760 residential properties, 6,025 people, 23 km of roads and 1,200 non-residential properties including the petrochemical complex, a major port and associated nationally important infrastructure (Falkirk Council and Jacobs, 2023). Some secondary drainage measures will also be integrated into the Scheme to protect against seepage and pluvial (high intensity rainfall) flood risk.

The Scheme flood protection measures within the six flood cells (Flood Cells 1-6) have been sub-divided into distinct Working Areas (Figure A1.3 in Appendix A). The Scheme components are shown in in Appendix A Figure A1.4 and Figures A4.1 to A4.28 and further referred to in Section 4.3.3. Figures A4.1 to A4.28 also show the Site Boundary and the Permanent Works Footprint and the type of flood defence wall e.g. bare sheet pile wall, formed concrete wall, stone clad wall in each Working Area. The Site Boundary comprises the area needed to construct the flood defences and is the area in which the contractor will be working. The Permanent Works Footprint comprises the permanent footprint of the proposed flood defences. A further set of figures, Figures A4.29 to A4.56, show the heights of flood defence walls and embankments relative to current ground levels. A detailed description of the Scheme according to Working Areas is provided in Appendix C4.3: Flood Protection Measures.

More information on the construction activities associated with the Scheme, including construction methodology, phasing and advance works, can be found in Appendix C4.2: Construction Methodology Report.

The Scheme shown in Appendix A: Figure A1.4 and Figures A4.1 to A4.28 has been developed to outline design, on which this EIA has been based. The outline Scheme design will be further developed at detailed design, which will be subject to all mitigation measures identified in this EIA Report that are applicable to the detailed design stage. Should any changes to the Scheme be required at detailed design, a review of such changes will be required to identify whether any additional impacts and potentially significant effects (that have not already been identified and considered as part of this EIA on the outline design) are likely. Any such changes will be subject to further environmental review, and any further mitigation identified to address potentially significant effects, with Falkirk Council's acceptance of these changes.

4.3.2 Climate change adaptation

The foundations of the flood defences have been designed, where feasible, to allow for an increase in their height by up to 0.7 m in the future, to mitigate the effects of climate change without requiring significant strengthening works, along with additional measures such as natural flood management. The specific height to which the flood defences are able to be raised will vary across the Scheme depending on the results of the hydraulic modelling undertaken at that time. As discussed in Chapter 1: Introduction, although the Scheme allows for these height raising measures to be implemented in the future, these measures do not form part of the Scheme as currently designed and therefore do not form part of this EIA. Any future proposals to implement measures that increase flood defence heights will

require further environmental review at that stage. The outline Scheme design also makes no provision to account for the significant additional lengths of flood defences or other measures that would be required to mitigate against this additional future flood risk. However, due to access, safety and constructability constraints along the estuary, such measures have been incorporated into the Scheme design at these locations along the estuary to avoid any future need to do so.

4.3.3 Scheme outline design

As discussed in Section 4.3.1, the outline Scheme design includes a combination of flood protection measures such as fluvial and coastal flood defence walls, earth embankments, a new flood control structure and relining of the existing flood relief channel. To accommodate these measures, the Scheme also includes flood gates, ramps, footpaths, ground raising, bridge raising, restoration of the river channel / banks, three replacement bridges, other bridge modifications as well as landscaping. The existing A9 (Beancross) underpass will also be blocked off and infilled with concrete.

A new at-grade, traffic signal-controlled crossing is to be provided on the A9 west of this underpass, although this does not form part of the Scheme design. It is envisaged that the basic infrastructure for the new crossing will be installed by Falkirk Council as part of a planned upgrade of the A9 / Grandsable Road junction which will be carried out in advance of Scheme construction in this area.

The height above ground level of flood defences varies along their length and these heights are shown in Figures A4.29 to A4.56. The specific flood defence heights at each section may be subject to refinement at the detailed design stage.

The outline Scheme design on which this EIA has been based represents a scenario that uses realistic maximum design parameters for the assessment in terms of what are assumed as contractor requirements to construct the Scheme and comprises the following:

- **Fluvial flood walls:** concrete or sheet pile walls with seepage control. The total length of both, fluvial and tidal flood walls across the Scheme is approximately 10.3 km. Flood defence walls are shown in Figures A4.1 to A4.28.
- **Coastal flood walls:** concrete walls with sheet piles and rock armour revetment to attenuate wave action. The total length of both, fluvial and tidal flood walls is approximately 17.6 km. Coastal flood defence walls are shown in Figures A4.1 to A4.28.
- **Earth embankments:** granular filled embankment with impermeable core (possibly clay, concrete or bentonite core). The total length of embankments is approximately 1 km. Earth embankments will be required at the following locations:
  - Flood Cell 1, Working Area 1-1 (Figure A4.1)
  - Flood Cell 1, Working Area 1-2 (Figure A4.2)
  - Flood Cell 2, Working Area 2-1 (Figure A4.5)
  - Flood Cell 4, Working Area 4-3 (Figure A4.14)
  - Flood Cell 4, Working Area 4-4 (Figure A4.15)
  - Flood Cell 4, Working Area 4-5 (Figure A4.16)
- **Flood gates:** used to control the flow of water at the following locations:
  - Flood Cell 1, Working Area 1-1 (Figure A4.1)
  - Flood Cell 1, Working Area 1-2 (Figure A4.2)
  - Flood Cell 1, Working Area 1-4 (Figure A4.4)

  - Flood Cell 2, Working Area 2-1 (Figure A4.5)
  - Flood Cell 2, Working Area 2-2 (Figure A4.6)
  - Flood Cell 3, Working Area 3-4 (Figure A4.10)
  - Flood Cell 3, Working Area 3-5 (Figure A4.11)
  - Flood Cell 4, Working Area 4-1 (Figure A4.12)
  - Flood Cell 4, Working Area 4-2 (Figure A4.13)
  - Flood Cell 4, Working Area 4-4 (Figure A4.15)
  - Flood Cell 4, Working Area 4-5 (Figure A4.16)
  - Flood Cell 4, Working Area 4-6 (Figure A4.17)
  - Flood Cell 4, Working Area 4-8 (Figure A4.19)
  - Flood Cell 4, Working Area 4-9 (Figure A4.20)
  - Flood Cell 5, Working Area 5-1 (Figure A4.21)
  - Flood Cell 5, Working Area 5-2 (Figure A4.22)
  - Flood Cell 5, Working Area 5-3 (Figure A4.23)
  - Flood Cell 5, Working Area 5-4 (Figure A4.24)
  - Flood Cell 6, Working Area 6-1 (Figure A4.25)
  - Flood Cell 6, Working Area 6-2 (Figure A4.26)

- **Seepage only flood defences**: the installation of piles in the existing ground without exposing the sheet piles above ground level.
- **Ground Raising:** areas where the existing ground level is raised by <0.5m. The raised ground may be surfaced with a material to allow a footpath or vehicular access. Ground raising is required to reduce the relative wall height adjacent to the Core Path between the River Carron and the Dawson Mission (Flood Cell 1, Working Area 1-2 and as shown in Figure A4.2).
- **Access Points (Ramps):** new ramp structures to provide access over the flood defences (refer to figures A4.1-A4.28).
- **Port of Grangemouth (Forth Ports) lock / storm gate:** the middle set of gates within the entrance channel at the Port of Grangemouth will be replaced with new bespoke flood gates. This will require the existing lock gates to be removed. (Flood Cell 3, Working Area 3-4 and as shown in Figure A4.10).
- **Flood relief channel relining:** the flood relief channel, which is a concrete / bitumen lined channel that was constructed in the 1960s to divert flow from the Grange Burn during storm events, will be relined to improve flows and repair damage (Flood Cell 4, Working Area 4-2 – 4-4 and as shown in Figures A4.13 - A4.15).
- **Flow Control Structure**: A flow control structure will be incorporated on the upper section of the Grange Burn, near the confluence of the flood relief channel and Grange Burn, to limit / control the downstream flow. The flow control structure will be an orifice with an overflow weir. (Flood Cell 4, Working Area 4-2 and as shown in Figure A4.12).
- **Zetland Park Kiosk:** the existing kiosk in Zetland Park will be demolished and replaced with a new kiosk (Flood Cell 4, Working Area 4-5 and as shown in Figure A4.16).
- **Culverts:** New and / or extensions to existing culverts will be required at the following locations:
  - Flood Cell 1, Working Area 1-2 (Figure A4.2)

- Flood Cell 6, Working Area 6-1 (Figure A4.25)

- **A9 (Beancross) Underpass:** the existing A9 (Beancross) underpass is subject to flooding and will be blocked off and infilled with concrete (Flood Cell 4, Working Area 4-1 and as shown in Figure A4.12).
- **Footbridges:** work to multiple footbridges on the Grange Burn and the flood relief channel, to incorporate new flood defences (involves reusing the existing footbridges but raising their height). This will include the raising of three existing footbridges (two on the Grange Burn and one on the Flood Relief Channel) at the following locations to tie in with the flood defences:
  - One footbridge in Flood Cell 4, Working Area 4-2 (Figure A4.14)
  - Two footbridges in Flood Cell 4, Working Area 4-5 (Figure A4.16)

  The works are expected to involve the following which have been used as maximum (realistic) assessment parameters:
  - The existing bridge deck will be removed.
  - The bridge abutments will be raised.
  - If required, piling work will be undertaken to the bridge abutments, (it is not envisaged at this stage for any piling work to take place within the river channel).
  - Where possible, the existing bridge deck will be re-used and lifted back into position. If the existing deck cannot be reused, a new deck will be installed.
  - No work within the river channel is proposed.
  - Any work above the river channel (across the river channel) will have appropriate mitigation in place to avoid materials / plant / people falling into the river channel.
- **Replacement Bridges:** existing bridges will be replaced at the following locations:
  - **New Carron Road Bridge**, Flood Cell 1, Working Area 1-2 (Figure A4.2). The New Carron Road Bridge is an existing single-span structure that carries a single lane, two-way carriageway (B902) and pedestrian footway (on downstream side) over the River Carron. From visual inspection, it is considered that the existing bridge could not withstand flood loading from a 200-year event and that the bridge deck would fail under buoyancy checks. Adapting the existing structure to withstand a 200-year event could be a complex and costly undertaking, therefore a purpose-built replacement structure with flood defences is required. The proposed replacement bridge will be constructed on the same alignment as the existing bridge and will be a single span structure, of similar deck length and width, adopting a similar footprint as the existing bridge. Construction form may vary with the new bridge designed to withstand flood loading up to a 200-year event.
  - **Reddoch Road Bridge**, Flood Cell 4, Working Area 4-4 (Figure A4.15). The existing Reddoch Road Bridge is assumed to comprise a single span reinforced concrete slab on cast iron beams which carries a single lane carriageway over the Millhall Burn. This structure would fail uplift forces from a 200-year flood event and will require replacement with a purpose-built flood defence structure which may take the form of a rectangular box culvert constructed of reinforced concrete construction and have a similar footprint to the existing bridge.
  - **Dalratho Road Bridge**, Flood Cell 4, Working Area 4-6 (Figure A4.17). The existing Dalratho Road bridge at the north end of Zetland Park is a multi-span structure that carries a single lane, two-way carriageway (Dalratho Road) over the Grange Burn, with pedestrian footways on either side. The deck is a reinforced concrete slab supported off reinforced concrete piers, located either side of the Grange Burn channel. The existing bridge would fail loading from a 200-year flood event and will require replacement with a structure that is expected to be constructed on the same alignment as the existing bridge with a similar footprint. The new

structure may be designed as a single span, removing the need for piers on either side of the channel, but this may increase deck thickness and reduce clearance below the deck soffit, subject to construction form.

A summary description of the proposed flood protection measures for the Scheme is provided in Table 4-3. Details of the measures proposed for each Flood Cell, divided by Working Area, are shown on Figures A4.1 to A4.28, with a further description of these provided in Appendix C4.3: Flood Protection Measures. The heights of flood defence walls and embankments are also shown on Figures A4.29 to A4.56.

Table 4-3: Proposed flood protection measures across the Scheme

Cell no.	Working Area / Figure	Location	Estimated overall length of flood defences in metres	Anticipated Form of Construction
1	1-1 / A4.1	Stirling Road	1611	Formed Concrete Wall, Brick Clad Wall, Seepage Only, Embankment
	1-2 / A4.2	Carron Bridges	1045	Brick Clad Wall, Stone Clad Wall, Stone Clad Wall with Glass Panels, Formed Concrete Wall, Embankment, Replacement Bridge (B902)
	1-3 / A4.3	Chapel Burn	685	Brick Clad Wall, Stone Clad Wall
	1-4 / A4.4	Dock Street	557	Formed Concrete Wall
2	2-1 / A4.5	Forth and Clyde Canal Lock	662	Embankment, Sheet Pile Wall
	2-2 / A4.6	Jarvie Plant/Rossco Properties	840	Sheet Pile Wall
3	3-1 / A4.7	Mouth of the River Carron	920	Sheet Pile Wall & revetment
	3-2 / A4.8	West Coast of the Port	965	Sheet Pile Wall & revetment
	3-3 / A4.9	West Gate to the Port	1167	Sheet Pile Wall & revetment
	3-4 / A4.10	East Gate to the Port	992	Sheet Pile Wall, Plain Concrete Wall, Formed Concrete Wall
	3-5 / A4.11	Mouth of the Grange Burn	683	Sheet Pile Wall
4	4-1 / A4.12	Upstream of M9	1078	Stone Clad Wall, Formed Concrete Wall
	4-2 / A4.13	FRC – Rannoch Park	559	Formed Concrete Wall
	4-3 / A4.14	FRC – Inchyra Road	505	Formed Concrete Wall & Embankment
	4-4 / A4.15	FRC – Whole-flats Road	2359	Formed Concrete Wall, Stone clad Wall, Sheet Pile Wall, Raising footway,

				Embankment, Regrading Existing Embankment, Replacement bridge (Reddoch Road)
	4-5 / A4.16	GB – Zetland Park	767	Stone Clad Wall & Embankment, Replacement Bridge (Dalratho)
	4-6 / A4.17	GB – Dalgrain to Bo'Ness Road	804	Stone Clad Wall
	4-7 / A4.18	GB – Grangeburn Road	1250	Sheet Pile Wall, Stone Clad Wall, Formed Concrete Wall
	4-8 / A4.19	GB – Petroineos	1051	Sheet Pile Wall, Stone Clad Wall
	4-9 / A4.20	GB – Mouth of Grange Burn	1142	Sheet Pile Wall, Seepage Only
5	5-1 / A4.21	Smiddy Brae & Avondale Road	1786	Sheet Pile Wall, Formed Concrete Wall
	5-2 / A4.22	Flare Road & Road 33	1102	Sheet Pile Wall, Seepage Only
	5-3 / A4.23	Grangemouth Road	1675	Sheet Pile Wall
	5-4 / A4.24	Mouth of the River Avon	438	Sheet Pile Wall, revetment
6	6-1 & 6-2 / A4.25 & A4.26	West of River Avon (Beach Road & Mouth of River Avon)	2166	Sheet Pile Wall, Bored Pile Wall with revetment
	6-3 & 6 - 4 / A4.27 & A4.28	East of River Avon (Chemical Works at River Avon & Water Treatment Works)	1422	Sheet Pile Wall & Embankment

4.4 Construction stage

4.4.1 Introduction

The EIA has been based on the construction methodology for the Scheme developed during outline design, and which is provided in Appendix C4.2: Construction Methodology Report. Construction methods will be developed further during the detailed design stage and from further liaison with stakeholders such as the statutory consultation bodies, landowners / operators, utilities companies and Falkirk Council. The design and implementation of temporary works, which includes construction access, will be proposed as part of the Contractor's method statements and submitted to the employer's representative for review and approval / acceptance by Falkirk Council and other regulators / stakeholders.

A Construction Environment Management Plan (CEMP) will be developed by the appointed contractor(s) in accordance with relevant standards and guidance.

Key aspects of the likely approach and methods for constructing the Scheme are summarised in the following sub-sections.

4.4.2 Anticipated construction programme

The Contractor will be responsible for developing the programme and sequencing of construction works, subject to any constraints imposed by the project team and / or planning / licence conditions. The construction period for the Scheme is estimated to be approximately 5 to 10 years (depending on how any construction contracts overlap), with discrete sections being completed in phases within that timeframe. A ten-year construction period has been used in this EIA which includes an initial (-1) year for pre-construction works. Construction works are anticipated to be carried out from Monday to Friday, over a period of 50 working weeks each year.

Indicative key dates for the anticipated construction programme are outlined as follows, however these are subject to change:

- Advance works: 2024.
- Main construction phase: 2025– 2033 (Scheme operational by 2034).
- Defects period: minimum two years post construction works (landscape maintenance period is to be confirmed).

4.4.3 Site compounds

An indication of proposed site compounds has been carried out by Jacobs, and it is estimated that 12 site compounds will be required for the construction works. It should be noted that due to the phasing of construction not all site compounds are expected to be active at the same time and additional site compounds may be proposed by the contractor. The indictive site compounds are shown in Figures A4.1 to A4.28 and are located within or adjacent to the main site boundary or where existing roads provide access to the works areas. As the availability of land for site compounds may change over the construction period, it is possible that their location may be revisited by the appointed contractor.

Any changes to the locations of these indicative site compounds or additional site compounds identified at a later Scheme design stage will be subject to an environmental appraisal, such that their residual environmental effects will not be greater than those identified in this EIA Report. The main site compound comprises offices, welfare facilities, parking and space for storage of materials and equipment. Additional smaller site compounds provide localised welfare facilities and storage to service the more remote work sections.

Site compounds are located as follows:

- Flood Cell 1, Working Area 1-1 (Figure A4.1).
- Flood Cell 1, Working Area 1-2 (Figure A4.2).
- Flood Cell 2, Working Area 2-2 (Figure A4.6).
- Flood Cell 3, Working Area 3-4 (Figure A4.10).
- Flood Cell 4, Working Area 4-2 (Figure A4.13).
- Flood Cell 4, Working Area 4-3 (Figure A4.14).
- Flood Cell 4, Working Area 4-4 (Figure A4.15).
- Flood Cell 5, Working Area 5-1 (Figure A4.21).
- Flood Cell 5, Working Area 5-3 (Figure A4.23).
- Flood Cell 6, Working Area 6-4 (Figure A4.28)

4.4.4 Enabling works

In advance of the main works contract, the following work may be carried out with the aim of reducing the risk of delay to the main works, provide greater certainty of cost, and to reallocate activities which are more suited to specialist contractors.

- Grangemouth contains numerous buried and overhead utilities, which may delay the construction of the flood defences due to associated proximity issues. To minimise this risk, each utility provider will be consulted to determine which utility can be diverted and which will have to be protected to enable the planning and implementation of the utility diversions to be completed in advance of the main construction works.
- There are a considerable number of above ground and buried pipelines within the Grangemouth area. Since not all of these are classified as utilities and some are privately owned, discussions are being held with private owners. However, it is unlikely that any of these pipelines will be diverted. As a result, some construction works for the Scheme will require additional (bespoke) work to protect the pipelines during the construction phase; this work will most likely take place during the main Scheme works contract.
- It is expected that temporary road and footpath closures or diversions will be required for some of the construction works, and it may be necessary to provide additional traffic management measures at some locations. This will be investigated further as part of a more comprehensive Scheme traffic management plan. Likely traffic management requirements per flood cell are provided in Appendix C4.2: Construction Methodology Report.
- To enable access to the banks of the various water bodies within the Scheme extents, numerous self-seeded and cultivated trees will need to be felled. This will be achieved by either felling the trees before the main works commences, or by making the main works contractor responsible for the felling. Further discussions will be required to determine the preferred method and timing of tree felling.

4.4.5 Main construction works

The main Scheme construction works will include establishing site compound and Working Areas, piling, earthworks, concrete construction, dismantling existing walls, movement of materials, wall cladding, surfacing and landscaping.

The buildings in Table 4-4 are expected to be demolished, including the kiosk in Zetland Park which will be replaced as discussed in Section 4.3.

Table 4-4 Buildings to be Demolished

Buildings	Flood Cell - Working Area	Ownership
Warehouse (Old Carron Works)	1-2	Private
Storage shed (timber yard)	1-4	Private
Storage shed (Jarvie Plant)	2-1	Private
Storage shed (Forth Clyde boat yard)	2-2	Private
Storage shed	3-1	Private
Storage shed	3-1	Private
Kiosk (Zetland Park)	4-5	Public
Storage building (Petroineos)	4-9	Private

The exact number of staff directly associated with the construction work is unknown, but it will comprise of operatives, managers, administration staff, supervisors and an environmental clerk of works, and is

estimated to be a minimum of 27 and maximum of 110 personnel during the peak period of construction. This number will fluctuate during the construction phases.

There are many constraints associated with construction works near rivers, namely the proximity of buildings, roads and other infrastructure on or adjacent to the riverbanks. As a result, some of the construction works will be required to be located on the 'wet side' of the proposed flood defences (i.e. from the side closest to the river), where access from the 'dry side' of the defences (i.e. from the side furthest from the river) is not considered feasible or where there are health, safety or access issues.

4.4.6 'Wet side' and in-river works

Wet side working will be undertaken either on the riverbank or be in-river works (i.e. works within the river channel itself). The in-river works extents are shown on Figures A4.1 to A4.28.

Installation of working platforms and river crossings will be carried out within the agreed times and confirmed prior to the construction works commencing.

The in-river works will be facilitated by temporary features. Raised working platforms are likely to be constructed from clean crushed rock placed on a separation geotextile and surrounded with a sand-filled bulk bag perimeter. The total length and the area of the working platforms will be confirmed at the detailed design stage. This will create a dry working area for personnel and machinery to construct the flood defences, and for plant to move between work sections on the wet side of the defences. The height of the platform will be confirmed at the detailed design stage.

Other options include the use of cofferdams, crossing points and temporary culverting of the channel. Cofferdams can be constructed around the working area to allow a dry area to be created where feasible. Where the presence of buildings or other barriers will prevent access to the riverbank, crossing points will be required.

Access to the in-river working areas in Flood Cells 1, 2, 3, 4 and 5 is anticipated to be achieved via a combination of ramps (existing and new ones), bridges and temporary construction bridges. In Flood Cell 6, access will be determined by the contractor, however, it is likely to be taken via a haul road constructed along the edge of the Firth of Forth Estuary, with the footprint of the haul road forming part of the foundation for the rock revetment.

As some of the watercourses and tributaries within the Scheme extents are relatively narrow, it may be feasible to temporary culvert short lengths (50 to 100m) of the channel, where required. This would allow a temporary working area to be created directly over the channel, and facilitate access to construct flood defences, which would otherwise require substantial working areas within the gardens of residential properties or require large temporary works on the existing banks to divert the channel or over pump water.

4.4.7 'Dry side' works

The remainder of the works are expected to be constructed solely from the 'dry side' of the Scheme and are likely to include earthworks and excavation works.

Excavations will be required for a variety of the Scheme works elements, particularly flood walls and embankments and these will be up to a maximum of 1 m in depth. Piling to greater depths will also be required beneath flood walls and possibly embankments, and it has been assumed that these would vary in depth, depending on the thickness of the superficial geological deposits in the locality and any relevant geotechnical requirements.

4.4.8 Disturbance to local traffic

It is anticipated that the works will result in some disturbance to local traffic, and temporary diversions and road closures may be required. The duration of closure will be dependent on the form of construction and constraints set by other stakeholders (owners, operators and Falkirk Council).

Several measures have been proposed in order to minimise the effects of construction traffic. Primarily, preferred routes have been identified to and from the site compounds and individual construction sites. It is also recommended that all construction traffic use the trunk road network or A-class roads and only deviate where necessary to reach individual sites. Several other traffic management measures have been proposed, including:

- Provision of alternative routes for diverted traffic and appropriate signage.
- Regulated site working hours in order to avoid heavy volumes of movement during peak hours in the morning and evening when general traffic levels will be higher than normal.
- Installation of additional (temporary) warning and speed control signs.
- Provision of a wheel wash facility and road sweeper to minimise any mud and debris on the surrounding public road network and prevent the introduction of non-native / invasive plant material to the site.
- Formation of a construction liaison committee to facilitate the smooth management of the project / public interface.
- Introduction of temporary parking restrictions and alternative parking arrangements where on and off-street parking is restricted as a result of the Scheme.
- Temporary closure of public rights of way and provision of suitable alternative routes.
- Stationing of a "Stop-Go" banksman to facilitate communication between drivers.

A Traffic Management Plan will be developed at the detailed design stage to further minimise the effects of construction traffic associated with the Scheme, and to provide reassurance to the local community.

4.4.9 Temporary flood protection and erosion protection

The sequence of construction work may have the effect of temporarily lowering the standard of protection of locations where flood defences have yet to be constructed. Temporary changes to the standard of flood protection are an inevitable consequence of constructing large flood protection schemes, since all flood defences cannot be constructed simultaneously. The appointed contractor will be required to provide temporary flood protection measures to maintain at least the current standard of protection across all extents of the Scheme to manage the temporary flood risk during construction.

Some temporary erosion protection of the riverbanks may be required, should the working areas increase the risk of scour. Such protection will take the form of geotextile and rip rap / armour stone and will only be implemented following a period of monitoring and discussion with the relevant stakeholders.

4.4.10 Reinstatement works

Working areas will be reinstated following construction. A like-for-like reinstatement of landscaped areas is likely to be provided, or alternatives could be developed in consultation with Falkirk Council as part of the detailed design phase.

Additional landscape and ecological mitigation measures within the Scheme, including replacement planting and the restoration of habitats, are proposed to be implemented through the detailed design process and through the adoption and implementation of a proposed Landscape and Ecological Habitat Management Plan (refer to Chapter 7: Biodiversity and Chapter 9: Landscape and Visual Impact Assessment).

4.4.11 Constraints on construction works

The Scheme represents a complex construction project, involving construction, logistics, river management, traffic management and public interface, and is spread over a large spatial area. Due to its scale and spatial extent, it is likely that at least four construction contracts would be required for the works. The sequencing and timing of these works is not yet confirmed; however, it is envisaged that the construction phase will take place over a period of approximately 10 years, therefore, some overlap of construction contracts is likely.

Whilst it will be for the contractor to establish a confirmed construction programme, the following restrictions on the sequencing of works will be incorporated into the contract requirements to manage the social and environmental impacts during the construction period:

- Restrictions to minimise disturbance to protected species and reduce adverse effects on designated nature conservation sites (further discussed in Chapter 7: Biodiversity);
- Restrictions on the total length of haul roads in place at any one time;
- Restrictions on the length of the working area which can be closed to the public at any one time;
- Restrictions on in-channel works that would prevent fish passage (further discussed in Chapter 7: Biodiversity); and
- Restrictions on work which disturbs the riverbed during salmon spawning season (depending on the limitations enforced in the CAR / Marine license) (further discussed in Chapter 7: Biodiversity).

4.4.12 Likely construction routes, plant, materials and waste

The main routes for construction traffic access into and out of Grangemouth are anticipated to include the A904 (Bo'ness Road and Grangemouth Road), A905 (Wholeflats Road and Beancross Road), B902 (Carron Road), A88 (Bellsdyke Road), A9, Inchyra Road, Stirling Road, Ronades Road, Powdrake Road, South Shore Road, Central Dock Road, North Shore Road, Forth-Clyde Way, Dalgrain Road, Clyde Street and Bothkennar Road.

At this outline stage in design, there is limited detail on the machinery and materials required and waste likely to be generated by the Scheme. However, Table 4-5 and Table 4-6 set out an indicative list of the likely equipment and materials required during the construction period. A more detailed list of equipment likely to be used is provided in Appendix B8.1: Noise Emission Database of Construction Plant Equipment in Chapter 8: Noise and Vibration.

Table 4-5: Indicative list of likely equipment to construct the Scheme

Indicative list of construction plant			
360 degree tracked excavators	Wheeled excavators	Dumpers	Mobile cranes
Tracked / non-tracked pPiling equipment	Vibrating roller compactors	Vibrating plate compactors	Concrete cutting equipment
Concrete pumps and skips and vibrating pokers	Burning and steel cutting welding equipment	Drilling and coring equipment	Mobile pumps

Indicative list of construction plant			
Mobile settlement tanks	Mobile generators	Mobile compressors	Mobile heaters
Tarmac planers and pavers			

Table 4-6: Indicative list of likely material to construct the Scheme

Indicative list of materials			
Cohesive fill for embankments	Granular fill	Sands, gravels, rock	Rock armour stone
Topsoil	Steel sheet piles	Contiguous piles	In situ concrete
Steel reinforcement	Geotextiles	Timber fencing	Metal fencing
Bitumen macadam	Plastic pipework and ductwork	Metal pipework	Concrete pipework
Mechanical/electrical pumps	Stonework, brickwork, and reconstituted stone products	Precast concrete products	Glass products
Metal and plastic fixings and fixtures	Hydrocarbon-based cellular products	Organic-based coatings and sealants	Hydrocarbon-based paints, coatings, and sealants
Lighting, wiring and fixtures	Fuel oils	Seed	Trees and plants
Flood gates	Lock gates		

The estimated quantities of materials required for the construction of selected structures included within the Scheme design are listed in Table 4-7.

Table 4-7: Indicative quantities of materials to construct the Scheme

Asset	Material	Measure units	Quantity
Embankments	Primary Aggregate	m^3	155,600
	Steel	m^3	1,230
Fluvial walls	Concrete	m^3	4,325
	Steel	t	606
	Steel	m^3	1,540
Tidal walls	Concrete	m^3	1,765
	Steel	t	247
	Steel	m^3	570
Bank Protection	Erosion matting	m^2	68,520
Rock Armour	Primary Aggregate	t	227,870
	Damp Proof Course / Membrane	m^2	58,430
Relining of Flood Relief Channel	Concrete	m^3	3,150
	Damp Proof Course / Membrane	m^2	31,500
Headwalls	Concrete	m^3	100
	Steel	t	14
Drainage pipe	Plastics	m^3	975
	Concrete	m^3	2,525
	Iron	m^3	3
Lock Gates	Steel	t	80
Flood Gates	Steel	t	15

Asset	Material	Measure units	Quantity
Weir	Concrete	m^3	21
Weir	Steel	t	3
Landscaping	Soil/Clay	m^3	24,000
Path	Asphalt	m^2	1,870
Culvert	Concrete	m^3	6
	Steel	t	1
	Primary Aggregate	m^3	140
Permanent access points	Primary Aggregate	m^3	20

At this stage of outline design, limited information is known about the waste that will be generated by the project. The detailed design will consider resource efficiency and waste minimisation in order to identify the materials that can be reduced, reused or recycled. However, it is anticipated that main waste is likely to comprise inert materials, potentially contaminated soils and made ground.

All such, waste will require disposal in accordance with legislative requirements, with waste that meets the landfill waste acceptance criteria taken to a local material recycling facility / landfill site. Any special waste designated under the Special Waste Regulations 1996 must be disposed in accordance with relevant SEPA guidance. The volume of special waste will depend on the extent of ground contamination.

The contractor will be required to prepare several management plans and method statements for carrying out the construction works. For example, the contractor will be required to prepare a Site Waste Management Plan, which will contain details of how different waste will be handled in accordance with the waste hierarchy and regulatory requirements. Also, as part of their method statements, the contractor will be required to propose appropriate methods for works at or near the water courses for managing sedimentation risk. These types of requirements are included as mitigation measures in this EIA (refer to Chapter 16 Schedule of Environmental Commitments).

4.5 Operation and maintenance

The Scheme has been designed to have minimal operation and maintenance requirements during its life (anticipated to be approximately 100 years). Once constructed, the Scheme will only require intervention to operate and maintain the flood defences by Falkirk Council and others. These will be set out in an operation and maintenance manual, which will be developed at a later stage. The key aspects will be:

- Closure of the flood gates during periods of predicted flood risk, and re-opening afterwards;
- Regular maintenance checks, such as the walls / embankments for structural defects, operation of flap-valves and potential for damage from vandalism. Flood gates and seals will be checked on an annual basis and, after a significant flood, to check for damage or wear and tear;
- Closure of Port lock gates and railway flood gates;
- Maintenance works as required, such as carrying out any pointing, cladding repairs, cleaning, replacing seals, vegetation clearance, removal of debris from bridges; and
- Landscape maintenance of the embankment and landscaped areas, as defined during detailed design.

Falkirk Council will be responsible for operating and maintaining the flood defences. The plant, materials and personnel required for the operation and maintenance works will be minor compared with

that required for the construction phase. At this stage, it is estimated that 2-5 personnel will be directly involved in the operation and maintenance of the flood defences, however this may significantly increase during a flood event.

As discussed in Chapter 1: Introduction and Section 4.3.2 of this chapter, the Scheme allows for future flexibility, in that flood wall foundations have been designed so that the height of the wall can be increased in the future without the need to re-construct the foundations. This measure would aim to mitigate the future impacts of climate change, where flood events are predicted to become more frequent and severe.

4.6 Demolition

It is not anticipated that the Scheme will be demolished within the foreseeable future, as the flood defence measures are expected to be maintained for around 100 years. Should demolition be required, however, it is anticipated that any future local authority will ensure that the relevant consents are obtained and environmental procedures are followed in accordance with relevant guidance.

4.7 References

Falkirk Council and Jacobs (2023) Grangemouth Flood Protection Scheme. [Online] Available at: https://www.grangemouthfloodscheme.com/ (Accessed January 2023)

SEPA (2015) Forth Estuary Local Plan District Flood Risk Management Strategy. [Online] Available at: https://www2.sepa.org.uk/frmstrategies/forth-estuary.html (Accessed January 2023)